(1) COPY to Bill

United States Department of the Interior

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FALLON, NEVADA
TAKE PRIDE IN AMERICA

September 28, 1992
File No. EC 42.4

Memorandum

To: Assistant Regional Director, Fish and Wildlife Enhancement, Portland, Oregon (AFWE-TS) Attn: Tom O'Brien

From: Field Supervisor, Reno Field Office, Reno, Nevada

Subject: Refuge Contaminant Cleanup Activities Reports

One Refuge Contaminant Cleanup Activities Report entitled "Mercury in Fish Collected From the Indian Lakes System Stillwater Wildlife Management Area Churchill County, Nevada" is attached. This is a final report. This project was initiated to assess the extent of mercury contamination in fish of five lakes of the Indian Lakes system on Stillwater Wildlife Management Area. There were no Federal or State mandates requiring action. The project name was identified as "Stillwater NWR (Indian Lakes)" in a FY 1991 Region 1 approved contaminant studies budget summary. The Regional Identification Number was 1261B. Total budget allocation was $6,000. A total of 19 samples was submitted for analysis under catalog number 1070006. The total catalog cost was $828.50. Field collections, sample processing, and catalog preparation required 4 biologist days. Staff cost for this phase (estimated at $500 per biologist day) was $2,000. The remaining project money was used for report preparation and review.

Service personnel were responsible for all aspects of the study. Personnel from the Nevada Department of Wildlife assisted with field collections. Copies of the report have not been distributed. Copies are intended to be sent to Stillwater National Wildlife Refuge and the Nevada Department of Wildlife. The Environmental Protection Agency may also be interested in study findings.

An interim report on the Stillwater/drainwater remediation project (FY 91 - 1CO2) will be submitted in December in accordance with the instructions of Tom O'Brien to Stanley Wiemeyer.

You may contact Stanley N. Wiemeyer of my staff at (702) 784-5227 if you have any questions regarding these reports.

David L. Harlow
David L. Harlow

cc:
Refuge Manager, Stillwater National Wildlife Refuge, Fallon, Nevada

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Mercury in Fish Collected From

the Indian Lakes System

Stillwater Wildlife Management Area

Churchill County, Nevada

Prepared by:

Peter Tuttle

U.S. Fish and Wildlife Service

Reno Field Office

September 1992

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INTRODUCTION

Elevated mercury levels have been identified in water, sediments, and biota in the Carson River drainage basin, west-central, Nevada. In some instances mercury concentrations exceeded levels considered safe for fish, wildlife, and humans. Of particular concern were game fish in the lower Carson River basin which may be consumed by humans. Many of these fish have been found to contain more than 1.0 $\mu g/g$ wet weight, the action level identified as safe for human consumption by the Food and Drug Administration (FDA 1984) and the Environmental Protection Agency (EPA 1989). Concern for human health prompted the Nevada State Division of Health to issue a health advisory for the consumption of game fish taken from waters of Lahontan Valley in April of 1987. This advisory included wetland areas on Stillwater National Wildlife Refuge (NWR) and Stillwater Wildlife Management Area (WMA), which is jointly managed by the U.S. Fish and Wildlife Service, the Nevada Department of Wildlife, and the Truckee-Carson Irrigation District. Within Stillwater NWR and WMA, the area of greatest concern is a series of lakes, the Indian Lakes system, which is managed as a recreational fishery by the Nevada Department of Wildlife.

BACKGROUND

Between 1859 and the turn of the century, mercury amalgamation was used in the milling of gold and silver ore from the Comstock Mining District in the Virginia Mountain Range approximately 70 miles west of Stillwater NWR (Smith 1943). As many as 186 mills, most of which were located near Virginia City or along the Carson River between Empire and Dayton (Figure 1), were in operation during this period (Ansari 1989). Some reports indicated that as much as 7,500 tons of elemental mercury may have been lost during milling operations (Bailey and Phoenix 1944). Most was discarded in mill tailings or discharged to the Carson River in mill effluent.

High mercury levels in sediment and water from the lower Carson River were identified by the U.S. Geological Survey in 1971, indicating that significant downstream transport of mercury had occurred (Van Denburgh 1973). In finding elevated mercury levels in fish collected between Lahontan Reservoir and Empire, Richins (1973) and Richins and Risser (1975) documented that mercury contamination extended to biological systems. Comprehensive studies of mercury contamination of water, sediment, and fish from the Carson River were undertaken in the early 1980's (Cooper 1983, Cooper and Vigg 1984, and Cooper et al. 1985). Cooper et al. (1985) assumed a mean concentration of 0.41 $\mu g/g$ wet weight in carp (_Cyprinus carpio_) muscle collected from Harvey's Ranch (Figure 1) upstream of mercury contaminated areas represented a background level for the Carson River system. Concentrations in fish increased downstream of Dayton. Mercury concentrations exceeded 1.0 $\mu g/g$ wet weight in 45 percent of fish collected below Dayton. They also demonstrated a correlation between mercury concentration in abiotic components (water and sediment) and mercury accumulation in fish in the Carson River.

Two lakes in the Indian Lakes system on Stillwater WMA, Likes and Papoose Lakes (Figure 2), were included in the studies of Cooper et al. (1985). Mercury concentrations in channel catfish (_Ictalurus punctatus_), white catfish (_Ictalurus catus_), white crappie (_Pomoxis annularis_), carp, and Sacramento blackfish (_Orthodon microlepidotus_) ranged from 0.24 to 2.12 $\mu g/g$ wet weight. Thirty-eight percent of fish collected from Likes Lake and 75 percent of fish collected from Papoose Lake on Stillwater WMA exceeded the 1.0 $\mu g/g$ level recommended for protection of human health by the Food and Drug Administration (FDA 1984). The highest levels were found in carp. Sevon (1986) assessed mercury concentrations in seven fish species from Big Indian Lake. In addition to those species examined by Cooper et al. (1985), Sevon (1986) also included white bass (_Morone chrysops_) and rainbow trout (_Onchorynchus mykiss_).

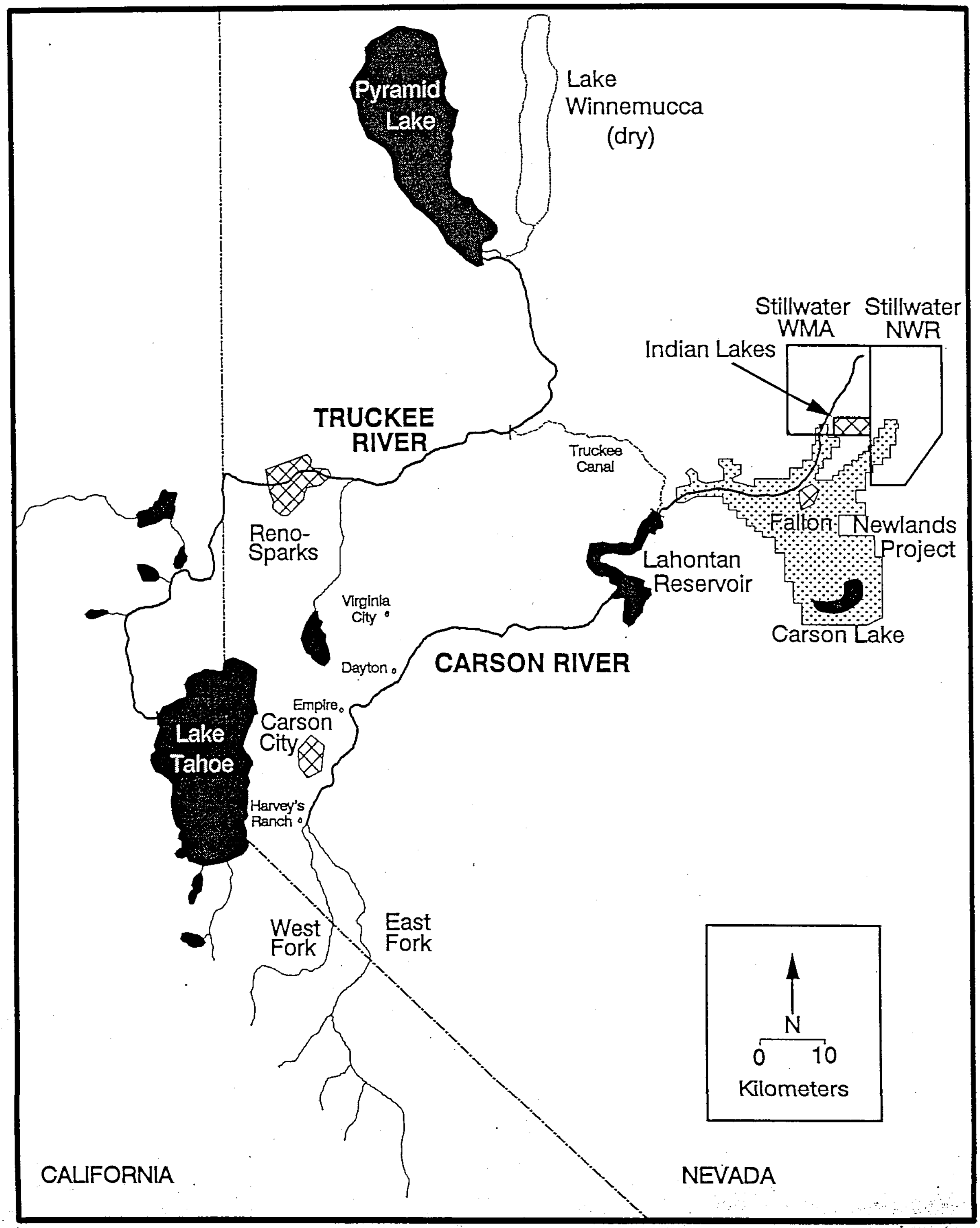

Figure 1. Map of Carson and Truckee River drainages showing Stillwater Wildlife Management Area and the Indian Lakes system.

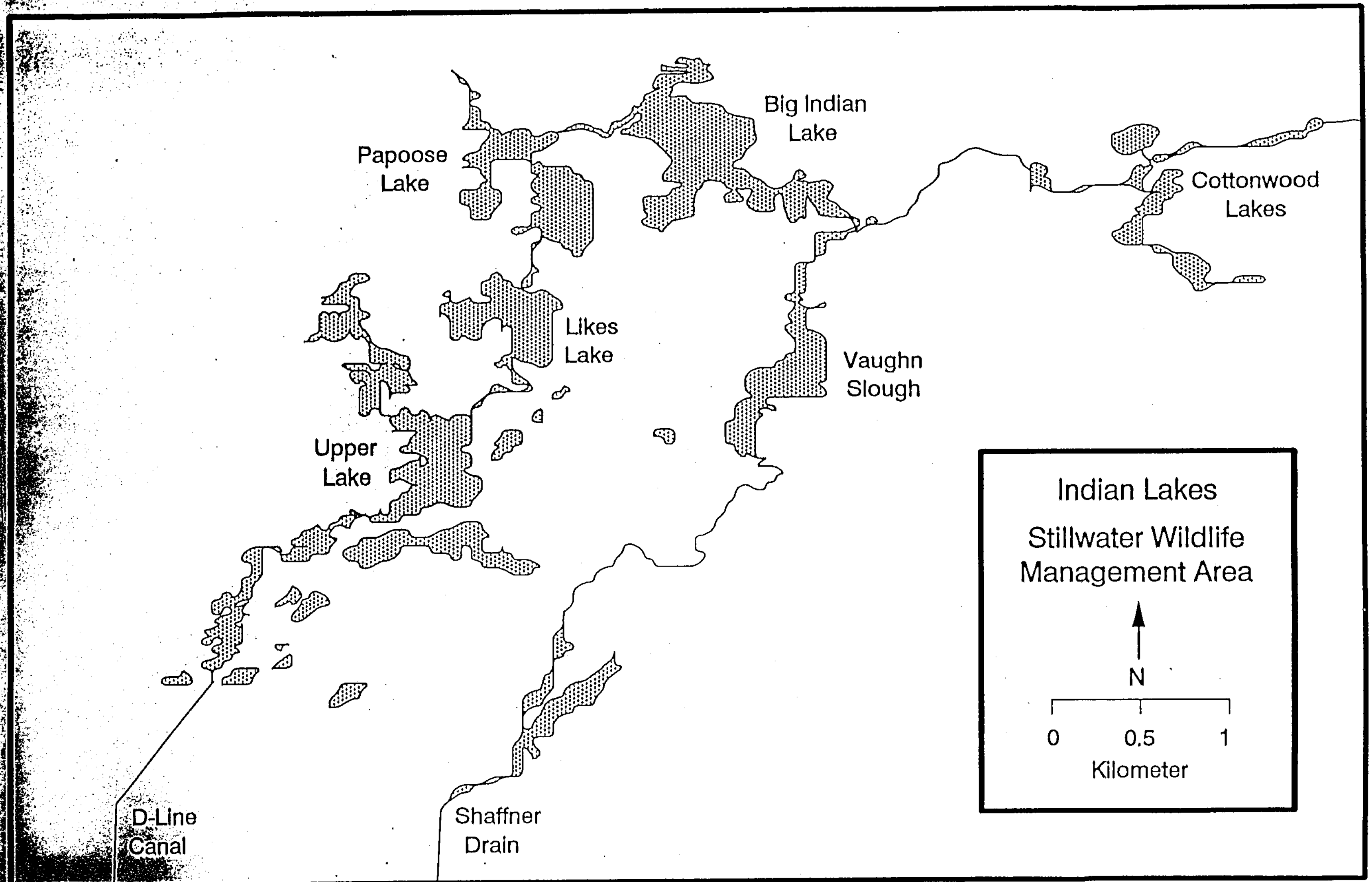

Figure 2. Map of major lakes and wetlands of the Indian Lakes system on Stillwater Wildlife Management Area, Churchill County, Nevada.

Mercury levels in this study ranged from 0.14 to 2.02 $\mu g/g$ wet weight. Fifty percent of these fish exceeded the FDA action level. The highest concentration was again found in carp.

U.S. Department of the Interior detailed studies of irrigation drainage further quantified mercury contamination in and near Stillwater WMA. Significant contamination of abiotic components, including water and sediment, was found (Hoffman et al. 1990, Rowe et al. 1991). Elevated levels of mercury were also found in plant, invertebrate, fish, and bird samples collected below Lahontan Reservoir. Organic material was identified as a primary pathway of biological exposure (Dr. Robert Hallock, U.S. Fish and Wildlife Service, pers. comm., 1991).

Concern for human health and environmental quality prompted the Environmental Protection Agency (EPA) to list the Carson River Mercury Site on its National Priority List in 1990. A Preliminary Natural Resource Survey for the Carson River Mercury Site determined that Department of the Interior Trust Resources may be adversely impacted by mercury in the Carson River basin (Ekechukwu 1991). Trust resources at risk include migratory birds, endangered species, and Category 2 candidates for listing as endangered or threatened under the Endangered Species Act of 1973, as amended. Endangered species identified on Stillwater NWR and WMA include bald eagle (Haliaeetus leucocephalus) and American peregrine falcon (Falco peregrinus anatum). Category 2 candidates for listing as endangered or threatened under the Endangered Species Act present on the area include ferruginous hawk (Buteo regalis), western snowy plover (Charadrius alexandrinus nivosus), mountain plover (Chradrius montanus), black tern (Chlidonias niger), western least bittern (Ixobrychus exilis hesperis), loggerhead shrike (Lanius ludovicianus), white-faced ibis (Plegadis chihi), and Nevada Oryctes (Oryctes nevadensis).

STUDY OBJECTIVES

This study was initiated by the U.S. Fish and Wildlife Service to assess the extent and severity of mercury contamination in fish collected from the five principal lakes of the Indian Lakes System. Specific objectives were to: 1) determine levels and assess variability of mercury in composite muscle samples from fish of two trophic levels collected from the five lakes; 2) assess variability of mercury levels in muscle of one fish species collected from one lake; and 3) identify lakes in which biological contamination has the potential to adversely affect fish, wildlife, and humans. The information will provide the basis to determine the need for remedial action and will aid in planning remedial activities.

STUDY AREA

Stillwater WMA, located in Churchill County, Nevada, occupies approximately 224,000 acres of historical marsh and upland habitat east and northeast of Fallon (Figure 1). The Indian Lakes system, a series of wetlands and impounded lakes and ponds, is located in the western part of Stillwater WMA (Figure 2). Major lakes of the complex include Upper Lake, Likes Lake, Papoose Lake, Big Indian Lake, and Cottonwood Lake. Under average water conditions, these lakes have a total surface area of 549 acres (Sevon 1988). Water is delivered to Indian Lakes through the D-Line Canal. Drain water also enters the system through Shaffner Drain. Water flowing from the Indian Lakes system is used to manage marsh units of Stillwater NWR immediately to the east.

The Nevada Department of Wildlife manages a warm water fishery in the five larger lakes in Indian Lakes. Principal game species include channel catfish, white catfish, black bullhead (Ictalurus melas), white bass, white crappie, yellow perch (Perca flavescens), largemouth bass (Micropterus salmoides), and walleye (Stizostedion vitreum) (Sevon 1988). The Nevada Department of

Wildlife also seasonally stocks trout in Likes and Big Indian Lakes. Trout stocking has included both rainbow trout and brown trout (Salmo trutta). Several other fishes occur in this system, including tui chub (Gila bicolor), Tahoe sucker (Catostomus tahoensis), Sacramento blackfish, carp, goldfish (Carassius auratus), bluegill (Lepomis macrochirus), green sunfish (Lepomis cyanellus), pumkinseed (Lepomis gibbosus) and mosquitofish (Gambusia affinis).

METHODS

White bass and carp were chosen to assess levels of mercury in fish from the Indian Lakes system because Cooper et al. (1985) recommended their use as indicators of mercury contamination in Lahontan Reservoir. These species represent two trophic levels; white bass are primarily picivorous while carp are omnivorous (Moyle 1976). Carp were collected from all lakes. White bass were not available in Upper Lake so white crappie were used to assess mercury levels in picivorous fish from that lake. White crappie also were collected from Papoose Lake for comparative purposes. To assess variability of mercury levels in one fish species in one lake, five white bass collected from Likes Lake were analyzed separately.

Fish were collected with gill nets on three occasions in November 1990. Fish were removed live from the nets and stored in an ice chest for a period not exceeding 8 hours before freezing. Fish were later thawed to remove muscle tissue. Muscle tissue between the lateral line and the dorsal fin was taken. Equal amounts (5 grams) of muscle were taken from each fish for composite samples. Twenty-five grams were taken for single fish samples. Tissue samples were placed in 2 ounce acid washed jars and refrozen. Stainless steel instruments washed with 20 percent nitric acid solution were used for dissections.

Tissue samples were submitted to Fish and Wildlife Service's Patuxent Analytical Control Facility, Laurel, Maryland. Mercury analysis was performed by Environmental Trace Substances Research Center, University of Missouri, Columbia, Missouri using cold vapor atomic absorption. Specific methods as described by Environmental Trace Substances Research Center are detailed in Appendix A. Average recovery of samples spiked prior to analysis was 108 percent.

RESULTS AND DISCUSSION

Mercury Concentrations in Fish Muscle

Mercury concentrations in muscle of fish collected during this study ranged from 0.5 to 2.7 $\mu g/g$ wet weight (Table 1). The highest concentrations were found in white bass (1.0 to 2.7 $\mu g/g$ wet weight; Tables 1 and 2) followed by white crappie (0.9 to 1.8 $\mu g/g$ wet weight) and carp (0.5 to 0.8 $\mu g/g$ wet weight). Concentrations in white bass of similar size collected from Likes Lake ranged from 1.0 to 1.4 $\mu g/g$ wet weight (Table 2).

Bioaccumulation and Biomagnification

Mercury has a high potential for bioaccumulation (Jenkins 1981, Eisler 1987). Accordingly, previous investigations in the Carson River basin have found evidence of bioaccumulation and bioconcentration (Richins 1973, Richins and Risser 1975, Cooper 1983, Cooper and Vigg 1984, and Cooper et al. 1985). These researchers found positive correlations between fish size and mercury concentrations, with larger fish containing higher concentrations. Small sample sizes collected during the present study precluded meaningful statistical analysis; however, no correlation between carp size and mercury content was apparent. Mercury concentrations in composite carp muscle samples collected from five lakes of the Indian Lakes system ranged from 0.5

Table 1. Species, length, weight, and mercury concentrations in muscle of fish collected in November 1990 from five lakes of the Indian Lakes system on Stillwater Wildlife Management Area, Churchill County, Nevada.

Species and collection sites	No. fish in sample	Length (mm)	Weight (g)	Mercury Concentration µg/g Dry Wt.	µg/g Wet Wt.
Carp					
Upper Lake	3	356 (248-456)[a]	1422 (920-2169)	2.6	0.5
Likes Lake	5	409 (387-439)	1225 (1046-1414)	3.8	0.8
Papoose Lake	5	391 (371-407)	986 (859-1118)	2.9	0.6
Big Indian Lake	5	453 (390-508)	1927 (1607-2383)	2.4	0.5
Cottonwood Lake	5	462 (454-486)	1802 (1634-1929)	3.2	0.6
White Bass					
Likes Lake	5	283 (266-299)	465 (367-526)	5.4	1.2
Papoose Lake	2	375 (372-378)	1311 (1299-1322)	8.6	1.9
Big Indian Lake	2	382 (360-404)	1271 (983-1558)	11.0	2.2
Cottonwood Lake	1	376	1090	12.7	2.7
White Crappie					
Upper Lake	4	229 (222-235)	209 (195-218)	8.5	1.8
Papoose Lake	3	243 (210-290)	344 (217-557)	4.1	0.9
Channel Catfish					
Big Indian lake	3	357 (332-379)	533 (410-658)	2.4	0.5

[a] Minimum and maximum values given in parentheses.

to 0.8 µg/g. The lowest concentration was found in a composite sample from Big Indian Lake which contained carp of the largest size. Richins (1973) noted that the correlation between size and mercury concentration was more apparent in picivorous fish. Mercury concentrations in white bass in the present study were lower in fish of smaller size collected from Likes Lake, suggesting a correlation between size and mercury content for this species.

Table 2. Length, weight, and mercury concentrations in muscle of white bass collected in November 1990 from Likes Lake, Stillwater Wildlife Management Area, Churchill County, Nevada.

Length (mm)	Weight (g)	Mercury Concentration µg/g Dry Wt.	Mercury Concentration µg/g Wet Wt.
299	526	5.4	1.2
285	463	5.8	1.2
284	506	4.8	1.0
283	462	5.5	1.4
266	367	5.7	1.2

Mercury also has a high potential for biomagnification in the food chain (Jenkins 1981, Eisler 1987). Again, previous research in Carson River has demonstrated biomagnification, with higher mercury levels found in fish of higher trophic levels (Richins 1973, Richins and Risser 1975, Cooper 1983, Cooper and Vigg 1984, and Cooper et al. 1985). Picivorous fish (white bass and white crappie) collected during the present study contained higher levels of mercury than omnivorous fish (carp) indicating biomagnification.

Mercury Contamination in Lakes of the Indian Lakes System

Mercury concentrations in carp muscle in the present study were only slightly above the background concentration (0.41 µg/g wet weight) for the Carson River as identified by Cooper et al. (1985). Concentrations in white bass and white crappie muscle were substantially greater; however, this could be due in part to their higher trophic level. Mercury concentrations in composite muscle samples were not highly variable between lakes (Table 1). Single fish samples of white bass of similar size collected from Likes Lake demonstrated limited intraspecific variability in mercury levels in muscle (Table 2).

Cooper et al. (1985) demonstrated a correlation between mercury concentrations in water or sediments and mercury concentrations in fish collected from specific sites. This suggests that fish are acquiring mercury at least in part from abiotic components at specific sites. Rowe et al. (1991) did not detect mercury in water discharging from the Indian Lakes system. However, Sevon (1986) found 6.25 µg/g dry weight mercury in sediment from Big Indian Lake. This level was substantially higher than the 0.41 µg/g dry weight background concentration in sediment identified by Hoffman et al. (1990). Rowe et al. (1991) also identified elevated mercury levels in detritus samples collected from Papoose, Big Indian, and Likes Lakes of 25.7, 52.6, and 97.8 µg/g dry weight, respectively. Levels found in Big Indian and Likes Lakes were the highest of 112 samples analyzed; levels in Pappose Lake ranked fifth.

Fish and Wildlife Concerns

Previous studies have found a wide variation of tissue levels related to mortality in fish. Niimi and Lowe-Jinde (1984) found that whole body concentrations up to 100 $\mu g/g$ wet weight were not lethal to rainbow trout[1]. Conversely, Armstrong (1979) noted that mortality of fish has occurred at total mercury concentrations in whole body between 5 and 7 $\mu g/g$ wet weight. Mercury concentrations found in Indian Lakes are well [?] levels documented to cause fish mortality.

Exposure to mercury can cause a wide variety of undesirable sublethal effects to fish and wildlife (Armstrong 1979, Eisler 1987). In addition to being carcinogenic, mutagenic, and teratogenic, mercury may cause adverse embryotoxic, cytochemical, and histopathological effects. Mercury also has been shown to adversely affect reproduction, growth, behavior, metabolism, blood chemistry, osmoregulation, and oxygen exchange in aquatic organisms. Unfortunately, tissue levels related to adverse effects in fish are not well documented.

Mercury concentrations found in fish in the Indian Lake system may adversely affect reproduction. Snarski and Olson (1982) found that fathead minnow (<u>Pimephales promelas</u>) reproduction was adversely affected by mercuric chloride at levels below 1.02 $\mu g/L$ in water. The tissue level of total mercury associated with this concentration after a 60 day exposure was 2.64 $\mu g/g$ wet weight. This finding suggests that tissue levels below 2.64 $\mu g/g$ may adversely affect fish reproduction. However, these data must be used with caution because fish are normally exposed to methylmercury in the environment, not mercuric chloride. Mercury concentrations in white bass samples in the present study from Cottonwood Lake exceeded this level, whereas concentrations in white bass from Papoose and Big Indian lakes and white crappie from Upper Lake approached it.

Snarski and Olson (1982) also observed reduced growth of larval fathead minnows at mercuric chloride concentrations in water of 0.5 $\mu g/l$. The whole body total mercury concentration associated with this exposure for 60 days was 1.24 $\mu g/g$ wet weight. Tissue concentrations in 5 of 12 (42%) picivorous fish samples in the present study exceeded this level, thus their growth may be adversely affected. However, this assumes no differences in sensitivity among species and no differences in toxicity between forms of mercury.

Wetlands in Stillwater NWR and WMA provide important foraging habitat for numerous picivorous birds. Most notably, this area has seasonally supported up to 70 bald eagles and 30,000 American white pelicans (<u>Pelecanus erythrorhynchus</u>). Mercury in fish of the Indian Lakes system may also represent a threat to these species. Heinz (1979) found that 0.50 $\mu g/g$ dry weight (equivalent to about 0.1 $\mu g/g$ in a natural succulent duck diet) of methylmercury in the diet adversely affected reproduction in mallards (<u>Anas platyrhynchos</u>). This dietary effect level is assumed to apply to other avian species. Mercury levels in all fish samples collected in the present study greatly exceeded this effect level. All samples also exceed the effect level for avian predators of 0.1 $\mu g/g$ as proposed by Eisler (1987).

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[1] Because mercury accumulates in axial muscle of fish whole body mercury concentrations are typically close to muscle tissue concentrations (Schmitt and Finger 1987).

Human Health Concerns

The Food and Drug Administration (FDA 1984) recommended that the mercury concentration in fish for human consumption should not exceed 1.0 μg/g wet weight. Recommendations by the EPA are consistent with this level (EPA 1989). All white bass from all five lakes and white crappie from Upper Lake collected during this study met or exceeded this level. White crappie collected from Upper Lake approached the 1.0 μg/g action level. All carp samples were below the action level. The EPA (1989) also indicated that a mercury level of 3.23 μg/g poses a 1:1,000,000 additional risk for cancer. All samples collected during this study were below this level.

Conclusions

Mercury concentrations in muscle of three species of fish collected from five primary lakes of the Indian Lakes system exceeded the carp muscle background concentration of 0.41 μg/g wet weight previously identified (Cooper et al. 1985). Concentrations were higher in picivorous fish than in omnivorous fish. The highest levels were found in white bass (1.0 to 2.7 μg/g wet weight), followed by white crappie (0.9 to 1.8 μg/g wet weight) and carp (0.5 to 0.8 μg/g wet weight). Differences in mercury levels were found between lakes; however, these differences were not consistent for all species.

Mercury concentrations in picivorous fish approached or exceeded levels that may adversely effect reproduction. Concentrations in all fish exceeded levels that may adversely effect avian predators. Mercury concentrations found in fish also exceeded levels considered safe for human consumption.

REFERENCES

Ansari, M.B. 1989. Mines and Mills of the Comstock region, western Nevada. Camp Nevada Monograph No.8.

Armstrong, F.A.J. 1979. Effects of mercury compounds on fish. Pages 657-670 in J.O. Nriagu (ed.). The biogeochemistry of mercury in the environment. Elsevier/North-Holland Biomedical Press, New York.

Bailey, E.H. and D.A. Phoenix. 1944. Quicksilver deposits in Nevada. Univ. of Nev. Bull. 38:12-46.

Cooper, J.J. 1983. Total mercury in fishes and selected biota in Lahontan Reservoir, Nevada. Bull. Environ. Contam. Toxicol. 31:9-17.

Cooper, J.J. and S. Vigg. 1984. Extreme mercury concentrations of a striped bass, Morone saxatilis, with a known residence time in Lahontan Reservoir, Nevada. Calif. Fish and Game 70:190-192.

Cooper, J.J., R.O. Thomas, and S.M. Reed. 1985. Total mercury in sediment, water, and fishes in the Carson River drainage, west-central Nevada. Nevada Division of Environmental Protection, Carson City, Nevada.

Eisler, R. 1987. Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85(1.10).

Ekechukwu, G.C.A. 1991. Preliminary Natural Resource Survey for the Carson River Mercury Site. U.S. Fish and Wildlife Service Unpubl. Report, Reno, Nevada.

Environmental Protection Agency. 1989. Assessing human health risks from chemically contaminated fish and shellfish: a guidance manual. EPA Report 503/8-89-002.

Food and Drug Administration. 1984. Compliance policy guidance for methyl mercury in fish. Report 7108.07, Federal Register, v. 49, No.45663.

Heinz, G.H. 1979. Methylmercury: reproductive and behavioral effects on three generations of mallard ducks. J. Wildl. Manage. 43:394-401.

Hoffman, R.J., R.J. Hallock, T.G. Rowe, M.S. Lico, H.L. Burge, and S.P. Thompson. 1990. Reconnaissance Investigation of Water Quality, Bottom Sediments, and Biota Associated with Irrigation Drainage in and near Stillwater Wildlife Management Area, Churchill County, Nevada, 1986-87. U.S. Geological Survey Water-Resources Investigations Report 89-4105.

Jenkins, D. 1981. Biological monitoring of trace elements. U.S. Environmental Protection Agency, Washington D.C. EPA Report 600/S3-80-090.

Moyle, P.B. 1976. Inland fishes of California. University of California Press, Berkeley.

Niimi, A.J. and L. Lowe-Jinde. 1984. Differential blood cell ratios of rainbow trout (Salmo gairdneri) exposed to methyl mercury and chlorobenzenes. Arch. Environ. Contam. Toxicol. 13:303-311.

Richins, R.T. 1973. Mercury content of aquatic organisms in the Carson River drainage. Unpubl. Masters Thesis. Univ. Nev., Reno.

Richins, R.T., and A.C. Risser. 1975. Total mercury in water, sediment, and selected aquatic organisms, Carson River, Nevada: 1972. Pestic. Monit. J. 9:44-54.

Rowe, T.G., M.S. Lico, R.J. Hallock, A.S. Maest, and R.J. Hoffman. 1991. Physical, chemical, and biological data for detailed study of irrigation drainage in and near Stillwater, Fernley, and Humboldt Wildlife Management Areas and Carson Lake, west-central Nevada, 1987-89. U.S. Geological Survey Open File Report 91-185.

Schmitt, C.J. and S.E. Finger. 1987. The effects of sample preparation on measured concentrations of eight elements in edible tissues on fish contaminated by lead mining. Arch. Environ. Contam. Toxicol. 16:185-207.

Sevon, M. 1986. Lahontan Reservoir Job Progress Report - 1986. Nevada Department of Wildlife, Fallon, Nevada.

Sevon, M. 1988. Federal Aid Job Completion Report, Indian Lakes and Stillwater. Nevada Department of Wildlife, Report No. F-20-24, Job 108-1 and 2, Fallon, Nevada.

Smith, G.H. 1943. The history of the Comstock, 1850-1920. Univ. of Nev. Bull. 37:41-47.

Snarski, V.M., and G.F. Olson. 1982. Chronic toxicity and bioaccumulation of mercuric chloride in fathead minnow (Pimephales promelas). Aquatic Toxicology 2:143-156.

Van Denburgh, A.S. 1973. Mercury in the Carson and Truckee River basins in Nevada. U.S. Geological Survey Open-File Report 73-352.

Appendix A

Methods as reported by Environmental Trace Substance Research Center, University of Missouri.

Homogenization

Large tissue samples, such as whole fish, were first run through a meat grinder one or more times depending on the size of the sample. An aliquot of the ground sample was weighed and frozen. For smaller tissue samples the entire sample was weighed and then frozen. The frozen samples were placed in a Labcono Freeze Dryer 8 until the moisture had been removed. The dry sample was then weighed and further homogenized using a blender, or a Spex Industries, Inc. Model 8000 mixer/mill with tungsten-carbide vial and balls.

Nitric Reflux Digestion for Mercury

Approximately 0.5 g. of sample was weighed into a freshly cleaned 50 ml. round bottom flask with 24/40 ground glass neck. Five ml. of concentrated sub-boiled HNO_3 were added and the flask was placed under a 12 inch water cooled condenser with water running through the condenser. The heat was turned up to allow the HNO_3 to reflux no more than 1/3 the height of the columns. Samples were allowed to reflux for two hours. Then the heat was turned off and the samples allowed to cool. The condenser was rinsed with 1% v/v HCl and the flasks removed. The samples were diluted with 1% v/v HCl in a 50 ml. volumetric flask and then transferred to clean, labeled, 2 oz. flint glass bottles.

Mercury - Cold Vapor Atomic Absorption

Equipment used for Cold Vapor include: Perkin-Elmer Model 403 AA; Perkin-Elmer Model 056 recorder; Technicon Sampler I; Technicon Pump II; a glass cell with quartz windows and capillary tube for entry and exit of the mercury vapor; and a liquid-gas separator. The samples were placed in 4 ml. sample cups at least 3/4 full. The samples were mixed with hydroxylamine for preliminary reduction, the stannous chloride for reduction of mercury vapor. The vapor was separated from the liquid and passed through the cell mounted in the light path of the burner compartment. The peaks were recorded and peak heights measured. The standardization was done with at least 5 standards in the range of 0 to 10 ppb. The correlation coefficient was usually 0.9999 or better and must have been at least 0.999 to have been acceptable. A standard was run every 8-10 samples to check drift in the standardization. This was usually less than 5%. Standards were preserved with 10% v/v HNO_3, 1% v/v HCl, and 0.05% w/v $K_2Cr_2O_7$. The solution concentrations were calculated and the data entered into the AA calculation program which corrected for blank, dilution, sample weight, sample volume and entered the data into the LIMS system for report generation.